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ARUBA'S HYDROPONICS FARM

In 1963 the island Government invited me to take charge of the hydroponics farm until another manager became available. Although I am not an expert in horticulture and gravel culture, the hydroponics system of growing vegetables has always fascinated me, and now, after a year of hydroponics, I believe that experiments of this nature may be of great importance for the development of horticulture in arid regions. Our experience may be useful to others working in this field.

It should be realised that critizing in retrospect is easier than planning a new enterprise well right from the start. Any criticism offered should be considered as a constructive attempt to improve this method of farming. It does not detract in any way from the author's appreciation of the initiative taken in starting a gravel culture in Aruba. May this hydroponics farm be the basis for a more up-to-date horticultural development in Aruba.

In the hydroponics system plants are grown in throughs filled with gravel, sand, vermiculite or any other material for supporting the roots. After several washings this material is supposed to be practically inert as far as supplying nutrients is concerned. The plants are fed by dissolving several elements in small concentrations in the water that is circulated through the throughs once or twice a day.

The old part of the farm was put into operation on 1st February 1958. It consists of 8 units of about 1 acre each. From the central tank of 40,000 gallons two open flumes run in opposite directions. On each side of the flumes there are 15 beds 100 ft. long and 3 ft. wide. The whole unit therefore consists of 60 beds. In the old part of the farm the beds are filled with crushed diorite (average size of the rock fragments 7 mm) mixed in some units with vermiculite.

Sub irrigation is applied. As shown in Fig. 1, the nutrient solution flows by gravity from the central tank into the flumes. From the flumes it enters the beds, where it runs over the bottom under half-round tiles. If the solution does not enter the flumes too fast, the level of the solution in the flumes and in the beds rises about equally.

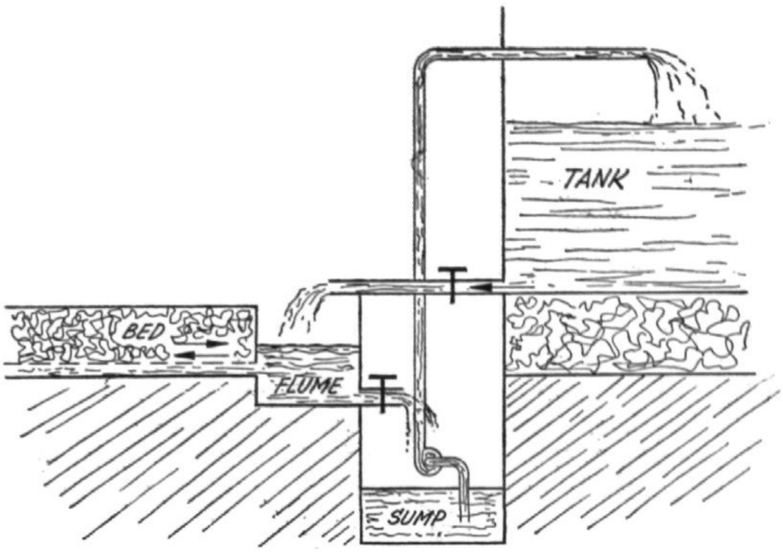

Fig. 1. Schematic drawing of the circulation of the solution: tank – flume – *beds* – flume – sump – tank. Compare Fig. 12.

Normally it takes 20 minutes to half an hour before the solution reaches the desired level. The valve from the tank is then closed, and the solution is allowed to stay at this level for 10 minutes. After these ten minutes the valves to the sump are opened, and most of the solution flows back into the sump, again by gravity. As the level in the sump rises, an electric pump is started automatically and pumps the solution back into the central tank.

In most hydroponics farms of this type the central tanks are constructed below the level of the beds. This has the advantage that after flooding the excess water will always flow back automatically into the tanks. We have had losses because the electric current failed during the stage of pumping the solution back to the tanks or because of heavy rainfall during the nights combined with failure of the pumps to start automatical.ly

Plants will suffer more from standing with their roots completely under water for a night, than remaining without water for a whole day. The reason for the erection of the tanks above the ground is that the suboil consists of very hard rock that would have made excavation very expensive.

An advantage of the location of the tanks above the ground is that in the circuit there are three stages in which the solution can be well aerated, as shown in Fig. 1.

In the construction of the farm some fundamental errors have been made:

(1) The farm has been built as a production farm. This is wrong. No data being available about horticulture on Aruba, the building of the farm should have been preceded by years of experimentation with small units. To experiment with the huge units we have now is very costly and sometimes even impossible. For instance, planting a quarter of a unit of cucumbers every two weeks the farm supplies the local demands and even exports 1000 kg per week. Should one want to get exact figures on water and fertilizer consumption, one would have to use at least half a unit (the beds around 1 flume) and leave the other half barren. But even with half a unit at a time there would be severe overproduction. If one should want to try several solutions at the same time, this overproduction would be even worse. Climatic circumstances are never parallel (rainfall), so that the comparison of different solutions in successive crops is not very dependable. As a consequence very necessary data are still lacking even after six years of operation.

Before construction was commenced thorough consideration should have been given to the following aspects and questions:

a. Construction of the beds; the length, width and depth and the material with which they are built are important factors. Especially in the old farm, where the ground has been levelled with loose sea sand, the 100 ft. long beds of reinforced concrete without expansion joints have proven to be too long. Extensive cracking has taken place.

Also the direction of the beds in relation to the wind direction or to the path of the sun may be important. All the present beds have been built at right angles to the wind direction, which causes the plants to be blown over the aisles, often making passage difficult.

b. What system should be used? There are several hydroponics systems in use in the world today. At least some of them should have been tested to find out which would have suited Aruban conditions best.

c. What varieties of the various vegetables would give satisfactory yields under Aruban conditions? Production of a crop should only be started on a larger scale after trials in small units have proven that the crop would be profitable.

d. The benefit or otherwise of using shade should have been evaluated for each crop. During the past year we have done some experimenting in this respect. Our provisional impression is that leaf vegetables will profit by shade, whereas those that form fruits will not.

e. Training and Mechanisation. No horticultural tradition exists on the island and the hot climate strongly diminishes the output of manual labour. Before starting in a big way it would have been desirable to be able to select the right people in a small pilot farm and to plan as much mechanisation as possible.

f. What material should be used to fill the beds? Up to now 4 different materials have been used, crushed rock, vermiculite, pebbles and natural diorite gravel. The last proved to be the best of these, but there remain many more possibilities to be tried.

g. A dependable protection against the strong continuous eastern trade-winds should have been found before a production farm was built.

(2) The ware-house and office have been constructed at the side of the farm instead of in the centre. This causes too much unnecessary walking.

Besides this, the building, which is long and narrow, has been built with a narrow side into the wind. Had it been built with its length facing the wind, the cooling of the building would have been better and at the same time the building could have served as a wind-break for one of the units.

(3) In a hot climate every possibility should be used to offset the effects of the heat. For the colour of the roofs of the tanks and the warehouse white or aluminium should have been chosen instead of red. We painted the roof of one of our tanks aluminium and compared the temperature of the solution in this tank with those of the surrounding tanks. Differences were between 1° and 2° Centigrade. This may not seem very much, but if one realises that the difference between the average maximum temperatures

of the hottest and the coolest months, like the difference between the average minimum temperatures in these months, is only 3° Centigrade and that this very small difference has exerted a great influence on the tomato production, it becomes imperative to try to profit from even the smallest differences.

In spite of the above-mentioned shortcomings, the financial losses of the farm during the first years of operation were only relatively small. The first management had the feeling that if the farm would be enlarged and the overhead costs thereby diminished, the farm would become profitable. In 1961 four units were added to the farm. These new units are similar to the old ones in size and design. The following improvements have been introduced:

Fig. 2. Sketch of old and new irrigation system. Compare Figs. 13-14.

(*1*). The nutrient solution is no longer led through the length of the beds under half-round tiles on the bottoms, but behind straight tiles leaning against one of the sides (see Fig. 2). This is cheaper in construction and much easier to operate. Every fifth tile slightly overlaps the preceding and following tile (dotted line in drawing), thus permitting it to check the free flow of the solution easily. Whenever the water passage has to be cleaned this is much more easily done along the sides of the beds than in the centres.

(*2*). In the old part of the farm after every 7 or 8 rows of beds a row of wind-breaks was situated. Each of these units thus has 4 rows of wind-breaks. These did not give sufficient protection. In the new units the same system for wind protection was followed, except that the wind-breaks were made higher and 8 rows of wind-breaks were built instead of 4.

(*3*). The crushed rock with which the old units are filled has rather sharp edges. These caused damage to the stems of the plants whenever they were moved by strong winds. On Aruba diorite formations occur that are already largely decomposed. After they have been blown up with a dynamite charge they disintegrate as gravel, which can be screened into different sizes. The edges of the little gravel stones are round. With this gravel (average diameter 8 mm) the new units have been filled. It works very satisfactorily.

(*4*). In the old units the ground had been levelled with sea sand that does not pack very hard. As a consequence the support of the long beds was not sufficient, causing a lot of cracking to take place. In the new units this levelling has been done with rather fine decomposed diorite. After some setting and a few rainfalls this packs very tightly, giving a good support to the beds. Much less difficulty is presented by cracking and leaking in the new units than in the old ones.

After the new units had been taken into use the financial results of the farm deteriorated rapidly instead of being improved as had been expected.

What happened?

Aruba has a very dry climate with an average rainfall of 20 inches a year. Yearly rainfalls can differ quite widely. As a rule a relatively good rain year is followed by four or five years in which the rainfall steadily decreases. After these years there is another good rain year followed by dry years, and so on in continuous cycles of 5 to 6 years.

The farm started operations in the latter part of such a rain cycle. As the sea sand with which the ground had been levelled and the gravel with which the beds were filled did not contain any weed seeds, the weeds did not constitute a great problem. As a consequence diseases and pests did not have much nourishment to survive between crops and the sprays reached the plants unhampered by weeds. Moreover, when one starts a new culture in new surroundings one has at least for the first few years the advantage of relative freedom from all the diseases that attack that culture. Sooner or later of course these diseases inevitably enter the new surroundings.

The winter of 1961–1962 was an exceptionally good rain season. All the weeds multiplied heavily, their seeds were either blown by the wind or carried by birds on the farm, where they became a big problem. Also in this period fungus diseases (early blight in tomatoes and leaf spot and powdery mildew in cucumbers) made their appearance on the farm and have never been eliminated since.

It was just at this time, when most management was needed, that the ratio of management to cultivated area had been reduced by the enlargement of the farm. In retrospect an enlargement of a farm, when the old farm had not yet been exploited to the utmost of its possibilities, must be considered a mistake.

A big fire that ruined the warehouse and destroyed the stocks of fertilizers, insecticides and fungicides further complicated matters.

The exploitation continued to give bad results all through the years 1962–1963. In August 1963 the island government of Aruba and the first management of the farm agreed to terminate the lease. The farm was incorporated in Aruminco (a government-owned corporation), and I was requested to take charge until another manager had been appointed. This temporary assignment lasted little over a year until September 1964, when the new manager took over.

In that year we attempted to analyze the difficulties experienced on the farm. Only after these difficulties are well understood can adequate solutions be found for them. Our difficulties can be divided into different categories, which will be discussed in turn.

Control of disease and pests

At the time of the change of management the farm was overgrown with weeds, spraying machines were in a very poor condition, and rats, mice, lizards and iguanas infested the farm in large numbers, causing considerable damage.

The spraying machines were repaired and a regular spraying programme was put in operation, which was not relented. Rat and mouse poison is laid regularly, lizards are caught in traps and iguanas are shot. These animals will never be completely eradicated, but their numbers can be kept down to a tolerable minimum. Constant vigilance in this respect is an absolute necessity.

Weeds remain a problem. Constant weeding is possible of course, but costly. We have not so far dared to use weed-killers. In normal soil rain will eventually wash away chemicals that have undesirable side effects. In our closed system this is difficult and, considering our high water cost, also very expensive. Covering of the beds with plastic mulch, originally done to save water, proved to be a very valuable help in weed control.

Covering of the aisles with concrete should be considered. This will eliminate the weeds there and at the same time help to spread the weight of the beds over a greater surface, thereby reducing cracking and leakage.

The following sprays are used on the farm at the moment:

on cucumbers and beans against red spider and aphids

250 cc Malathion 60 %	emulsifiable concentrate	per 50 gallons
250 cc Endrin 19,5%	,,	,, ,,
118 cc Teepol		,,

and against leafminers, leaf spot and powdery mildew

350 cc Diazinon 20% e.c.	per 50 gallons
200 grams Karathane 25% wettable powder	,,
118 cc Teepol	,,

On tomatoes against leaf roller, leaf miner and early blight

350 cc Diazinon 20% e.c.	per 50 gallons
450 grams Copper sulphate	,,
118 cc Teepol	,,

These sprays are applied at least once a week. In the earlier years of the existence of the farm the spreader-sticker of Dupont and De Nemours was used. Later on, the farm switched to the use of Teepol, a synthetic soap made by Shell, which is much cheaper but serves the purpose equally well.

WHITMAN (4) advised us to revert to the use of the spreader-sticker of Dupont and De Nemours, because of its excellent qualities. I do not think that this is necessary during the dry months of the year, but I do think that it should be considered for the wet months. During the rainy season we see a flare-up, notwithstanding the spraying, of fungus diseases, especially leaf spot and powdery mildew. We have ascribed this to higher air humidity, but it can also be explained of course by the probability that during rainfall Teepol (being a synthetic soap) is washed away with the fungicides.

The above-described spraying programme is not completely satisfactory. In the first place the breaking down period of the Diazinon is too long to be able to use it during harvesting and at the same time bring vegetables free of insecticides on the market. Malathion that is short acting does not have any effect on our leaf miners and leaf rollers. It has been planned to try out Phosdrin for this harvesting period. This has not yet been done because the Phosdrin would necessitate spraying two to three times a week, which at the present time would interfere with the rest of the spraying programme.

The sprays applied at the moment keep the leaf miners under control but never eradicate them on the farm. Leaf rollers are even more of a problem. Once they have rolled themselves in the leaves they cannot be reached with the sprays. We have applied Phosdrin that works systemically, but without any success. No dead caterpillars were found in the days following the spraying. So in fact there must be always a sufficient amount of insecticide on the leaves to kill the little caterpillars as soon as they come out of the eggs. To ensure this and keep the leaf rollers out, Diazinon must be sprayed twice a week. But in that case one will have to bring contaminated vegetables on the market.

Parathion was the only insecticide used on the farm that completely eradicated leaf miners and leaf rollers. But after 5 casualties through

Parathion misuse occurred in one year in the Netherlands Antilles the use of this insecticide was forbidden. The farm should not try to obtain exemption from this rule since if it were the only user of Parathion, it would automatically be blamed by public opinion for any accidents that might happen with Parathion which has come into circulation in some irregular way.

A new chloro-carbon insecticide 'Telodrin' has proved to be unsuccessful against our leaf miners and leaf rollers.

So far the species of the leaf rollers and the leaf miners that attack the plants of the farm have not been determined. An investigation of the species and of their life cycles may open new possibilities for fighting them and for controlling the damage caused by them.

Reduction of water costs

Because the former management had always devoted a lot of attention to the large share of the total expenses accounted for by water, we also have given this problem much thought.

In the cool climate of the Netherlands a tomato plant will consume an average of nearly 3 liters water per day (Steiner). Under our conditions we should of course reckon with an even higher consumption. A high water consumption is, therefore, inevitable for a large-scale production. All our fresh water must be distilled from the sea, however, and is consequently very expensive. The water price for the farm at NAf. 1.— (roughly US$ 0.50) per cubic metre is cheap by the standards of our island, but must be considered very expensive when compared to the price of agricultural water elsewhere. This makes it an absolute essential to prevent every unnecessary loss of water. During this last year the following measures were taken to economize as far as possible on the expenses for water:

1. We introduced jiffy pots, in which the plants are raised primarily to achieve a higher occupation of the beds. With direct seeding, either some seeds did not come up or some young plants would die for one reason or another. Consequently the beds had an irregular aspect and did not attain their maximal productivity. After raising seedlings in jiffy pots only strong and healty plants were transferred to the beds, which improved uniformity as well as productivity.

The saving of water in the first period of the growth of the plants, when the pots stand close together, proved to be so big that it more than offset the costs incurred for the pots and the extra labour, so that we had all the advantages of improved production, shorter occupation of the units and an advantage over the weeds at no extra costs.

2. The strong trade winds blow in the longitudinal direction of the flumes. During the inflow, which lasts only half an hour, not much water is lost through evaporation. But during the backflow of the solution when the last water seeps out of the gravel during the hottest hours of the day, it stands to reason that a large part of this water must be lost through evaporation. We were able to obtain ridge tiles of an outdated model quite cheaply. We have painted these aluminium on the topside and black on the underside and have used them to cover as many flumes as possible.

3. At the same time we have ordered black plastic mulch from the USA to prevent evaporation from the surface of the gravel and also to prevent the growth of weeds. To produce the latter effect the mulch had to be black. We were wondering whether this black mulch would not attract too much heat to the beds. This did not seem to be the case. The uncovered beds were not less hot at midday than the covered ones. Particularly in the old units, the rather dark gravel adsorbs a considerable amount of heat. Moreover, the very smooth surface of the plastic has a mirror like effect. And last but not least, the gravel stays much moister much longer under the plastic, thus also adding a cooling effect to the beds.

Reduction of wind damage

Wind-breaks were built as a protection against the wind. They consist of a vertical lattice work with laths of about 1 inch wide and spaces between the laths of about 2 inches. In the old units there is a row of such wind-breaks after each 7 or 8 rows of beds. These have not given sufficient protection. In the new units their number was therefore doubled and they were made higher. Nevertheless, even in the new units protection against wind damage is insufficient.

This is because of the fact that the setup is actually fundamentally wrong. What is the case?

In the first place too much wind filters through the laths, especially on very windy days, and in addition the wind will

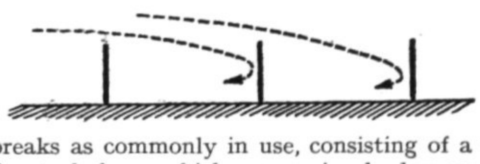

Fig. 3. Wind-breaks as commonly in use, consisting of a vertical lattice work, causing turbulence which may seriously damage the plants.

roll over the top of the wind-break, hit against the next and cause a turbulence. This process is illustrated below (Fig. 3).

The beds just before a wind-break, whether in an old or a new unit, always show most wind damage. The object should have been to control the air currents rather than to try to break them.

Over the few trial units we have, we therefore tried out another form of wind protection, combined with a trial designed to show whether shade would be beneficial to our tomatoes. Saran shade cloth was put over the beds in the form of a shed roof (Fig. 4). By means of a strongly smoking fire at the windward side of these beds the air currents were made visible and were found to behave in accordance with our expectations.

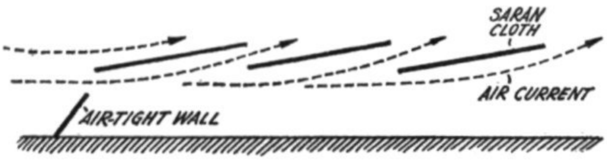

Fig. 4. New kind of wind-breaks, consisting of a shed roof of saran shade cloth behind an air-tight wall, causing a controlled air current which flows over the top of the plants.

A controlled air current goes over the top of the plants and has a cooling and no longer a destroying effect.

Not all crops, however, will benefit from shade. The next step should be to check for all the different crops whether shade will be beneficial or not and, if so, what percentage of shade results in optimal production.

For crops, requiring optimal sunlight the following system should be tried, whereby the existing wind-breaks are tilted on their supports and the following situation is caused (Fig. 5).

The practicality of this system has still to be proved.

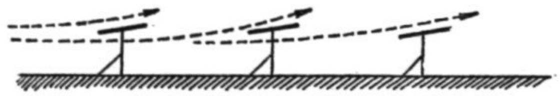

Fig. 5. Proposed new kind of wind-breaks for crops which do not benefit from shade, whereby the existing windbreaks are tilted on their supports.

Production

In the earlier years the complete farm used to be in production during the cooler months. As a result of the introduction of jiffy pots and the increased productivity per unit and also because of the fact that we have not achieved the volume of sales that has been possible in some of the former years, we have never had the farm in full production during the past year. It is therefore absolutely essential either to extend the number of crops or to increase the sales of the existing products by price reductions.

The various crops and their possiblities will be briefly discussed below.

Cucumbers. In the first years of the farm's existence the varieties Palomar, Ashley and Palmetta, which are not resistent to mosaic virus, were grown successfully. The Palomar variety was the best, giving yields of up to 6 tons per quarter unit in 9 weeks (6 weeks growing and 3 weeks picking). In May 1960 the farm was struck by a strange disease, causing all cucumber plants of a unit to wilt very suddenly. No signs of known cucumber diseases could be found. Dr. S. P. DOOLITTLE of the U. S. Dept. of Agriculture Crops Research Div., Beltsville, Maryland, infected cucumber plants with material from wilted Aruban plants and in this way obtained outspoken signs of mosaic virus disease.

From then onwards mosaic virus resistent cucumber varieties have been used on the farm. First the varieties Ohio 200 en Burpee hybrid. These were a lot less productive under our conditions than the variety Palomar, yielding at best 3 tons per quarter unit. After these the varieties Salad Chief and Challenger were tried, the first of which is slightly superior under our conditions to the latter. We have had trouble, however, in obtaining sufficient seed of Salad Chief so that we mostly worked with Challenger during the past year. This variety is very satisfactory, giving yields of up to 6 tons per quarter unit.

During the past year, being three years after the wilting disease, the varieties Palomar and Ashley were tried again, but immediately fell victim to the wilting disease.

In the last few years cucumbers (and also other cucurbits, such as melons and West-Indian gherkins) started to grow progressively less well in the old farm. It has now come to the point, where cucurbits can no longer be grown successfully in the old units. We have tried unsuccessfully to find out the reason for this phenomenon. It is not impossible, however, that the less good oxygenation of the solution in the old units is the cause. In the old units the oxygen saturation of the solution at the inflow is 79% and in the return 57%, whereas these percentage in the new units are respectively 89% and 66% (our medical laboratory was kind enough to make these determinations).

This difference is important since the solubility of oxygen in water is already low at the prevailing temperature (average 30°C), 7.52 mg per litre, whereas it is 10,07 mg per litre at 15°C.

When we presented our cucumber difficulties to Mr. A. A. STEINER (3), of TNO, Naaldwijk, Holland, he suggested a low oxygen content of the solutions as one of the possible causes.

This low oxygen content prevents a breaking down of the organic secretions of the roots by oxidation or by bacteria, that also need oxygen for their activity. As a result these secretions may reach a toxic level. It has not been proved yet that this is the reason of the difference in the productivity of cucumbers in the old and in the new units.

The better oxygenation of the solution in the new units must be attributed to the better aeration of the solution during its passage through the beds, where every fifth tile gives an open connection to the outside air, whereas in the old units there is no open connection to the outside air at all.

After the difference in the growth of cucurbits had been noticed, these crops were kept away from the old units. Further by rotation of crops in the new units an attempt was made to prevent the building up of toxic secretions. In other crops such as tomatoes, peppers and beans, no differences in productivity between old and new units were observed.

The use of jiffy pots has been of great importance for the cucumber culture. Instead of 9 weeks, the units are now occupied 7 weeks only. This reduced the total number of quarter units used for cucumbers from 4–5 to 3–4.

As only strong young plants are planted out, the production per quarter unit is practically consistently 6 tons per crop instead of only reaching this peak once in a while.

Notwithstanding the fact that the prices were lowered 30%, cucumbers are our most profitable crop. It must be regretted that local consumption of cucumbers is small and greater sales of this very good crop are not forseeable in the near future.

West-Indian Gherkins. By transferring this crop to the new units and by using jiffy pots and black plastic mulch, the farm now obtains a greater yield in a quarter unit than in a whole unit a year ago. The plant is well adapted to local circumstances and not very sensitive to diseases.

As regards profitability this crop is the farm's second best, with a steady though not overlarge demand.

Melons. Melons had been grown as an experiment in former years, but the attempt had been abandoned because results were disappointing. In view of the success with the two above-mentioned members of the cucumber family we decided to give melons another chance.

It proved essential to tie up the plants. In those that we left lying down most fruits cracked with the heat as soon as they became so big that they were no longer covered by the leaves.

In the course of the years the following varieties have been grown: Medium Persian (the fruits were too big and prone to cracking), Rio Gold (after a few good fruits too many too small fruits are produced), Edisto (the taste left much to be desired), Smith Perfect (does well but does not produce a very attractive looking fruit), Schoon's Hardshell (the best so far).

Additional difficulties in the case of melons are that quite a large number are lost through theft and that the market is soon oversaturated.

Tomatoes. As far as acreage is concerned this is the most important crop of the farm, but seen from a standpoint of profitability it takes only a third place, actually being too near to the break-even point. In the

Netherlands Antilles large amounts of tomatoes are consumed. The farm could have this whole market if the tomato price could be brought down 20%. At present the farm only has the largest part of the luxury market in which a higher price is paid for a better tomato.

In the case of tomatoes the farm has not been so lucky as in that of cucumbers in finding a good variety that is well adapted to our local conditions. Trial crops of a considerable number of varieties have been grown in the course of the years: Homestead 61, Homestead 24, Pink Deal, Pan American, Burpee Hybrid, Grossen Globe, Urbana, Money Maker, several strains of Elsa Craig, Mana Lucy, Mana Lee, Firesteel, Hot set and six hybrids obtained from the University of Hawaii.

Of these, Homestead 61 proved to be the best in the cool months of the year, with Pink Deal in the second place. The tomatoes are planted with three-week intervals between the different units from September to February, so that fruits can be harvested from the end of December until June. The yields are not very satisfactory, not more than 8 tons per crop per acre.

All the other varieties, even Mana Lucy, which has such a good reputation throughout the Caribbean, performed unsatisfactorily.

Up to last year the farm had never been successful in producing tomatoes during the hot season. The plants would grow very well, producing a lot of foliage, but very little fruit. This confirmed the experience of other horticulturists (Chinese and Portugese) on Curaçao and Aruba. Also in former gravel-culture experiments in Curaçao and Aruba tomatoes could not be grown in the hot season. Amongst people with agricultural experience on our islands it is therefore considered impossible to grow tomatoes in this season.

Nevertheless, it would be of the utmost importance to the farm to be able to grow tomatoes all the year round, not only because there is a steady demand for this product, but also to keep the clients attached to the farm. Now every year our tomato clients, who have placed standing orders abroad during the hot season, must be won back during the cool season, which is not always easy.

We decided therefore to try again with Homestead 61, Pink Deal and six heat-resistant tomato hybrids that we obtained from the University of Hawaii. We are very happy to be able to report that we achieved reasonable production from the Pink Deal variety. The others did not perform satisfactorily.

To find ways to enlarge the productivity per acre several experiments have been set up to study the influence of shade, a better wind protection, different types of gravel, another way of tying up the plants and other ways of irrigation. The farm should continue to search in every possible direction to find the way to improved productivity per acre. If costs could be brought down with greater mechanisation and efficiency and the yields per acre could be raised, it should be possible to lower the price of the tomatoes. The whole market on Aruba and Curaçao would then be open for the tomatoes of the farm, giving it the stable financial backbone it needs.

Cherry Tomatoes. A good product from a strong plant in all seasons, and not very sensitive to diseases. Because of the small size of the fruits the picking costs are rather high. Cherry tomatoes are therefore somewhat more expensive than normal tomatoes and will never be a mass product.

Two other small fancy tomatoes were tried in the first years of the existence of the farm, i.e. Yellow Pear and Yellow Plum. They grew equally well. However, the public preferred the Cherries and since the market is too small for three fancy tomatoes, production of the Yellow Plum and Yellow Pear had to be discontinued.

Peppers. Peppers alone are too expensive to produce by our system, but if they are grown between the tomatoes, they can be an attractive source of extra income.

Three varieties have been tried, Yolo Wonder, Florida Giant and California Wonder. The first is the best of these under our conditions, giving the largest fruits and the highest yields.

Beans. On the farm a long bean (*Vigna sinensis*) is grown, but no profit is made on this crop. The plants grow well, but the beans are so light that notwithstanding a relatively high price the total income from the crop is too low. The only reason why it has been kept is the desire to be able to offer the client a more extensive assortment of vegetables.

The beans have reacted well to the new formula of our nutrient solution, which has a lower osmotic value and a higher nitrogen content. This, together with the introduction of plastic mulch, may enable us to approach the break-even point for this crop.

Scallions. This is an ideal crop to plant in beds that are left over for some reason or another. There is a small but steady demand for this product.

Grapes. Through the kind cooperation of Mr. A. A. STEINER 25 grape cuttings were received. They are progressing well. The vines are led over the upper wires of the trellises. The idea is that they will not only produce fruit, but also supply shade for the plants underneath.

Raspberries. They have been tried but were a failure.

Brocoli. It grew well and produced flowers of a good quality. The growing period is too long and the yield is too small to be profitable in an Aruba gravel culture.

Leaf Vegetables. In an effort to extend the assortment we have done our best during the last year to obtain seed and information on leaf vegetables that can be grown in the tropics. So far Purslain and *Basella rubra* (eaten as spinach) have been added to the farm's list of crops. In former years lettuce was planted as an experiment. It grew well but tended to grow bitter very quickly.

The first efforts to create a local market for these leaf vegetables have been disappointing. The public is so used to the canned or deep-frozen leaf vegetables of cooler climates that it is hard to get them to buy the fresh product.

Flowers and Ornamental Plants. WHITMAN (4) advised us to develop this possibility also. Although it should not be disregarded, difficulties in distribution should be taken into account. The former management of the farm introduced roses. They grew well and developed many flowers, but selling them on the local market proved to be difficult. Activities in this sector should be started on a small scale and only be extended with the growth of the market on our island and abroad.

NUTRIENT MEDIUM

During the past year a regular correspondence on this subject was maintained with Mr. A. A. STEINER (3), head of the Dept. of Soilless Culture of the National Research Council (T.N.O.) in the Netherlands.

Our formula for the nutrient solution was compared with the Naaldwijk summer formula.

In summer the plants will transpire more water than in winter. As vegetables are roughly 90% water, a sufficient uptake of water is of obvious importance for good production. To facilitate this uptake of water the osmotic value of the Naaldwijk formula is lowered in summer. At a temperature of 25°C the Naaldwijk summer formula has an osmotic value of 0.73 atm., whereas at the same temperature our solution has an osmotic value of 0.87 atm. Since plants grow and produce well on the summer formula in Naaldwijk and our temperatures are mostly nearer to 30°C, it seemed worthwile to lower the osmotic value of our solution.

In addition the nitrogen content of our solution was very low, compared with that of the Naaldwijk solution.

Following STEINER's directions for formulating a nutrient solution, we changed our formula as follows:

element	*old formula concentration in ppm*	*new formula concentration in ppm*
K	300	250
Ca	200	170
Mg	40	33
Fe	4	4
N in NH_4 form	35	30
N in NO_3 form	100	150
P	70	63
S	q.s.	q.s.

To this formula the following trace elements were added once a month:

12 g Boric acid crystals	per 1000 gallons	(for tomatoes double this amount).
4 g $MnSO_4$. 4aq (24.6% Mn)	,, ,, ,,	
1 g $CuSO_4$. 5aq (25.5% Cu)	,, ,, ,,	
1 g $ZnSO_4$. 7aq (22.7% Zn)	,, ,, ,,	
0,5 g Na_2MO_4. 2aq	,, ,, ,,	, which will give an M concentration of 0.045 ppm.

This also seemed to be a rather high dosage, which was given in Naaldwijk only once per tomato crop of 7 months. Since plants do grow faster in the tropics and the weeds at our establishment still compete quite heavily for the nutrients, we decided to add the trace elements once every three months.

In view of the rather large quantity of trace elements added, STEINER wondered whether Boron poisoning might not be the cause of the stunted growth of the cucurbits in the old units. Samples of the nutrient solution of an old and a new unit were forwarded and a rather high boron concentration was in fact found in the sample of the old unit. Samples from the tanks of the other old units, however, did not show such a high boron content.

Also cucurbits continued to grow poorly in the old units even when trace elements are withheld for some time. This makes it unlikely that too high Boron concentrations are the cause of the unsatisfactory growth of cucumbers in the old units.

The results of the change in formulation are difficult to ascertain. It has already been suggested earlier in this article that the farm is not suitable for experimentation. In general it has been our impression that the plants withstand rather wide fluctuations in concentrations of the different elements without many complications. Only in the beans is the yellowing of the leaves which should be ascribed to a nitrogen deficiency, no longer in evidence. Also the beans are now giving a better yield.

Next to the nutrient solutions, consideration was also given to the substrate of the plants. In Naaldwijk rather coarse gravel is used in which the plants are irrigated twice a day. In Aruba the beds are filled with much finer gravel. Originally the plants were irrigated twice a day. Subsequently the former management changed this to once a day. This resulted in a considerable saving of water, while yields remained practically the same.

To compare the two systems under Aruban conditions a small experimental unit was filled with coarse pebbles and irrigated twice a day; a second unit was filled with the gravel that is used on the farm, and was irrigated once a day. The difference was striking. In the coarse pebbles the plants practically failed to develop, whereas they flourished in the fine gravel. The explanation is probably a rapid drying out of the roots in the coarser pebbles at our temperatures.

A comparison was also made between growing tomatoes by the Dutch system of gravel culture and the American sub-irrigation system, on the basis of which our farm has been built. Regrettably a heavy attack of leaf rollers disturbed this trial just after the first fruits had been set so that no conclusions can be drawn as yet about possible differences in yields. The tomatoes did grow slightly better by the Dutch system, but used about 25% more water. This trial must be repeated, but with our high water cost it is clear that production will have to be considerably higher using the Dutch system to offset this disadvantage.

Labour

Notwithstanding the fact that the farm pays very low wages, the labour factor weighs too heavy on the total result of the farm. This is not surprising since even the hard working Chinese horticulturists on the island hardly can compete with imported vegetables. Although these Chinese are reputedly good market gardeners and are willing to work 12 hours a day, they still do not seem to get any richer from their efforts. Nevertheless the imported vegetables are not sold at 'dumping' prices. This means that elsewhere, with high wages and modern social laws, these vegetables can be grown at a profit.

This must be explained by two factors, higher yields per surface unit (in the foregoing several aspects of this factor have been discussed), and higher efficiency.

As to the latter, it is still low, but several attempts have been made during the past year to find improvements.

1. It is amazing how minor measures sometimes can result in considerable savings. Formerly all the labourers used to go to the warehouse to drink. As a consequence workers were leaving the field all day long at the slowest possible pace to drink water. Each trip lasted at least half an hour and the boys averaged four trips a day. We bought some insulated water cans, which are put in the refrigerator in the afternoon and brought out in the morning to the units where the boys are working. The workers like to have the cool water nearby and a lot of time that was needlessly spent on walking is now used for their work.

2. At the advice of FELTON (1), a systemic insecticide that can be added to the nutrient solution was used. Shell Netherlands

Antilles Sales Company kindly supplied us with Phosdrin for this experiment. Phosdrin was added in a concentration of 1 ppm to the nutrient solution. In co-operation with Aruba's medical laboratory the number of days the Phosdrin took to disappear from the solution was investigated. The concentration of the Phosdrin dropped too low within three days. At the chosen level of 1 ppm aphids and red spider were killed, but leaf miner and leaf roller were not. The addition of Phosdrin to the solution in higher amounts would become more expensive than the present spraying method.

3. WHITMAN (4) advised the use of a baby tractor for several chores on the farm and suggested alterations to the units to permit maximum use of such a tractor. Contact has been taken up with a tractor manufacturer and the possibilities of its use are under study. The alterations comprised covering the flumes with a concrete slab and piling up material on both sides of the flume, to make it possible for a tractor to cross to the other end of the unit and come back along the next aisle (Fig. 6-7). However, instead of covering the whole flume with one concrete slab I should prefer to put concrete slabs on the flume between the aisles only and to cover the flume between the beds with loose covers of the type now being used, so as to provide an access for outside air and to facilitate periodic cleaning.

4. Our own thinking tended rather in the direction of a bigger tractor on stilts. To enable the farm to profit fully from such a tractor the system for tying up the plants should be changed. A new system for tying up the plants is being tested.

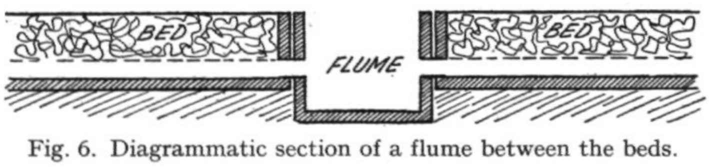

Fig. 6. Diagrammatic section of a flume between the beds.

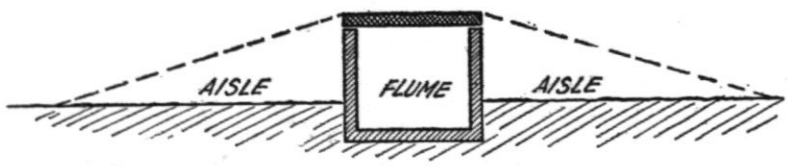

Fig. 7. Diagrammatic section of a flume covered by a concrete slab and with concrete ramps to allow a tractor to pass over it.

5. Every day two people are busy opening and closing the valves. On Sundays overtime must be paid for this work. The possibility of installing automatic valves is therefore being studied.

CONCLUSIONS ABOUT THE FARM

During the past year the downward curve representing the farm's results has been turned upward, notwithstanding a price reduction of 30% in the most profitable crop. An improvement in the production of tomatoes may put the farm on a profitable basis. It is of utmost importance to examine every possiblity of realising this. With some good luck the solutions to the farm's problems may be found within a short period of time. If this is not the case, courage should not be lost too soon. From whatever has been achieved during the past year and from the results in other tropical countries it does not seem overoptimistic to envisage the future of the farm with confidence.

Ultimately the farm can be an appreciated source of work for some young Arubans and a highly esteemed source of fresh vegetables for the community.

Is the gravel culture system to be preferred for the future horticultural development of the leeward islands of the Netherlands Antilles?

In my opinion it is not.

What are the advantages of the hydroponics system?
(1). It saves labour in the preparation and possibly fumigation of the soil and in watering the plants.
(2). No water is lost to the deeper layers of the soil.
(3). It has been claimed that in the gravel culture system higher yields can be obtained. (This has never been proven. Of course if one wants to compare a hydroponics farm to one using soil, both should be of the same technical level. Since in modern horticulture soils can be given the desired chemical and physical structure, there is no reason why gravel culture should give better results.)

The hydroponics system also has a few very important disadvantages.
a. The building costs for a hydroponics farm are very high.
b. Maintenance of the units and the pumps is not inexpensive.
c. All the necessary nutrients for the plants must be bought, whereas the soil will supply at least some of them.

d. Keeping the concentration of the necessary elements and the pH at their desired levels requires a lot of knowledge, attention and time.

Looking more closely at the advantages, we must remember that especially in recent years many machines have come on the market which mechanize a number of the tasks entailed in horticulture. These machines are much cheaper than the cost of building a hydroponics farm and they have largely been developed for normal horticulture in soil. Hydroponics is such a small sector of horticulture and there is such a variety in the farm designs that practically no machinery has been developed to fit the special needs of gravel culture. If one is employing normal horticulture in soil, it is not too difficult to change the lay-out of the farm to exploit the special possibilities of certain mechanical equipment. In hydroponics of course one lacks this versatility, which can make it difficult to profit fully from the newer possibilities in mechanisation, for instance in spraying, picking, laying out of plastic mulch etc.

In this industrial age it is of the utmost importance for agriculture to mechanize to keep up in productivity with industry. On Aruba this is even more true. The intense heat between the plants, where wind circulation is low, is detrimental to the output of manual labour.

The necessity of fumigating the soil has so far not arisen on the farm. Greater ease in fumigating the soil is therefore not yet a factor of importance.

Watering of the plants can be automated with tubes and sprinklers or with sprinkler hoses.

It is of the utmost importance to save water in the Netherlands Antilles. The prevalent water prices make the use of this water profitable only when top production can be achieved. And as pointed out earlier in this article, we are still far from such production levels, except possibly in cucumbers.

What happens to the water that falls on the soil?

1. A part of it will evaporate from the surface of the soil;
2. A part will adhere to particles of the topsoil;
3. Part of this water will be used by weeds;
4. Another part will be used by commercial plants;
5. The excess will drain away to deeper layers the soil.

It is only this last part that is saved in a hydroponics system.

As mentioned earlier, the losses as a result of 1 and 3 can be reduced by the use of plastic mulch. The amount of water available to the plants mentioned under 2 largely depends on the nature of the topsoil. HENRIQUEZ (2) mentioned the poor physical structure of the Curaçao soils and recommends for horticulture a 1:1 mixture with peat-moss to improve this structure. On the other hand, the chemical composition of our soils, which are all freshly decomposed volcanic rock, should be reasonably good, as shown by the abundant plant growth in years in which the rain showers are well spaced. A better structure will improve the accessibility of the soil to air and water, and the water-holding capacity of the topsoil.

It should not be difficult for the not too learned horticulturist to ascertain how many minutes of sprinkling are required before the topsoil is saturated with water. Topsoil is mostly very thin on Aruba and deeper layers are rather impenetrable for water. This explains the high percentage of rainwater running off to sea instead of being absorbed. For the same reason, however, not too much of the irrigation water will be lost to deeper layers, provided the precaution is taken of not giving too much water at a time.

At the beginning of this article I stated that the hydroponics farm can be great importance for the development of more modern horticulture in the Netherlands Antilles. It will do this in two ways.

(1). Because of its intricacy the farm will always have to employ managing personnel of a more elevated level of training. It is to be expected that this personnel will introduce more modern ideas into local horticulture. Some techniques that prove to be a success on the farm are soon copied by local horticulturists, as has been seen in the past.

(2). In the gravel culture system the water and fertilizer requirements of the various crops at different stages of their growth and under Aruban conditions can be established.

The necessary amounts of water with the necessary fertilizers added to it can be fed to the plants through a sprinkling system. This work can be easily automated with a time clock and an electric pump. Supposing that five minutes of sprinkling would saturate the topsoil and twenty minutes of sprinkling would be necessary to supply the day's water requirement of the crop, the pumps could easily be set to work four times for five minutes at intervals in the course of the day.

Combining the desirable features of farm lay-out discussed in the foregoing, we arrive at the following ideal for soil horticulture. After the beds have been prepared by working peat-moss into the soil by tractor driven equipment, sprinkler hoses are laid out, after which the beds are covered with plastic mulch, again with the use of tractor drawn equipment. The aisles between the rows of mulch are for walking and permit at the same time rain-water to enter the ground (Fig.8). Further, the lay-out be

Fig. 8. Diagrammatic sketch of a lay-out for a horticultural farm: beds provided with sprinkler hoses and covered with plastic mulch.

so chosen that the tractor can be used for planting, spraying, picking and removing the old plants. The structures for tying up the plants should be removable so that full profit can be derived from the tractor in taking out the old plants.

Aruba, November 1964.

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The photographs were made by Dr. P. WAGENAAR HUMMELINCK (8. XI. 1963), with the exception of Figs. 9 and 12 which were rendered available by Voorlichtingsdienst Aruba.

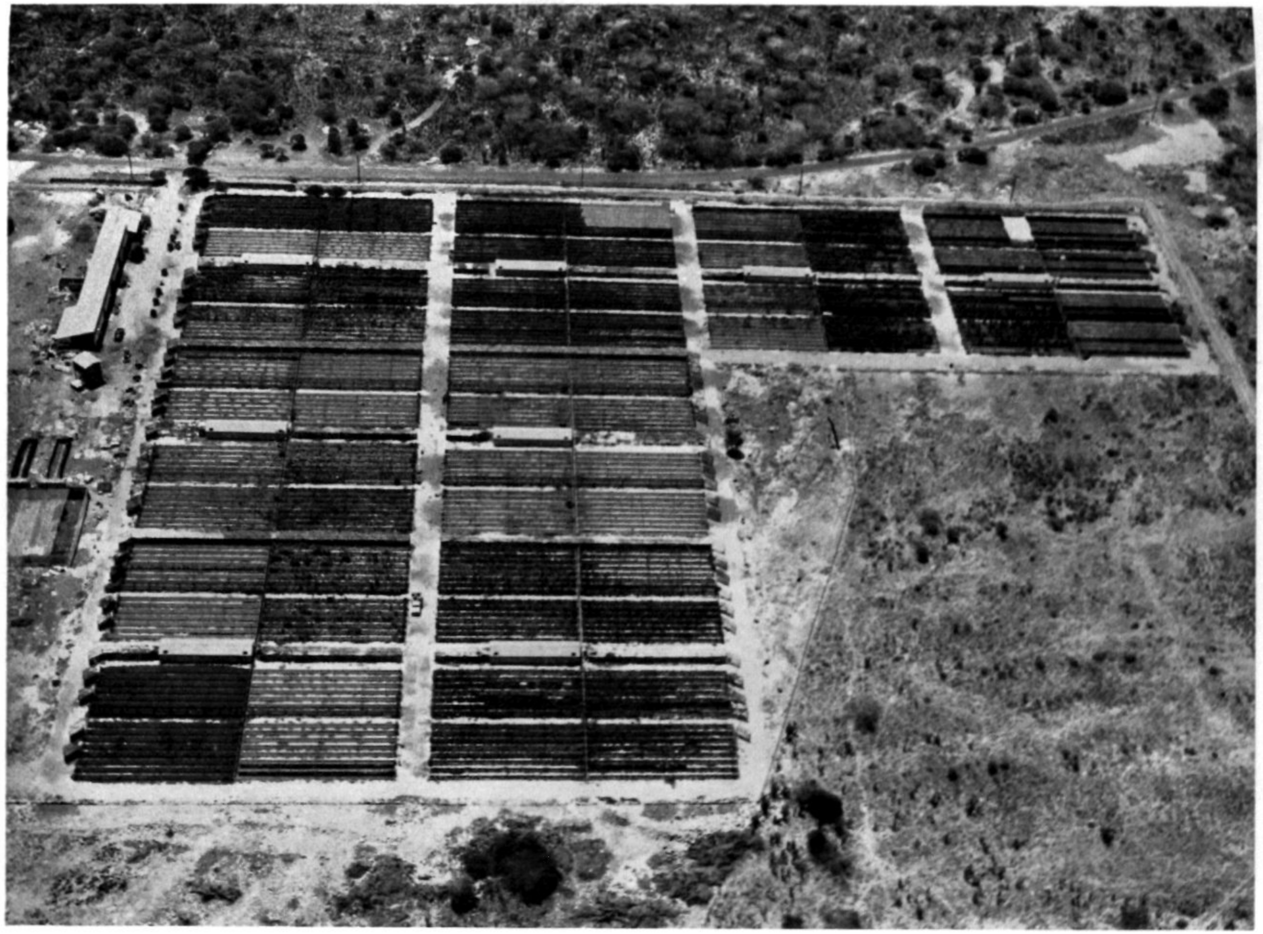

Fig. 9. Aereal view of the eight old units of the farm, with the office-warehouse building on the left. The flumes dividing the units in two can be clearly seen. Less distinct are the sumps at the head of the tanks.

Fig. 10. Office and part of warehouse.

Fig. 11. Wind-breaks and trellises as now in use on the farm.

Fig. 12. Visit of the prime minister of the Netherlands, Prof. J. de Quay (1961). The photograph shows the wall of one of the tanks, the valves through which the solution runs into the flume and the flume with beds on both sides.

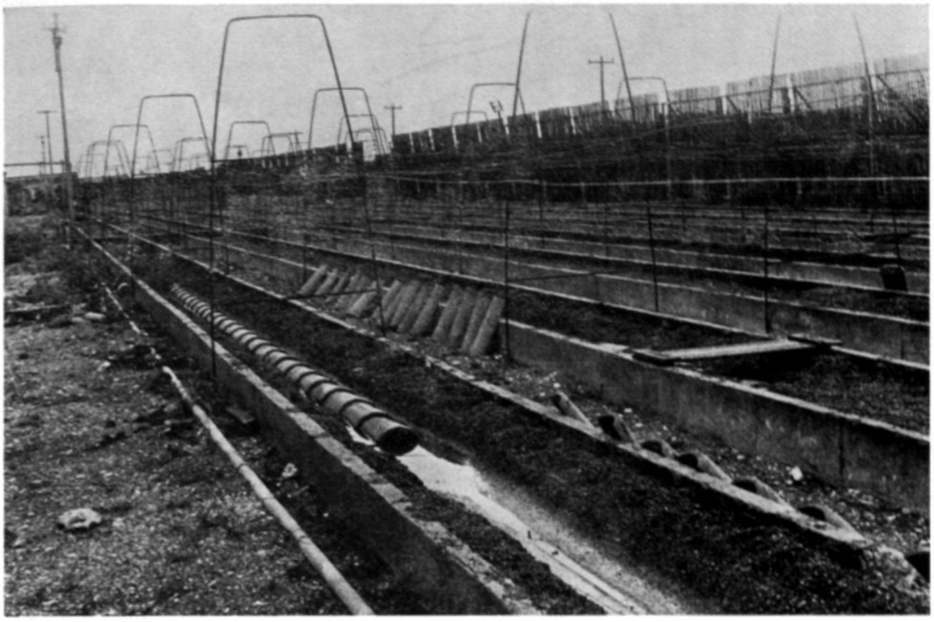

Fig. 13. Irrigation system in old unit. Compare Fig. 2.

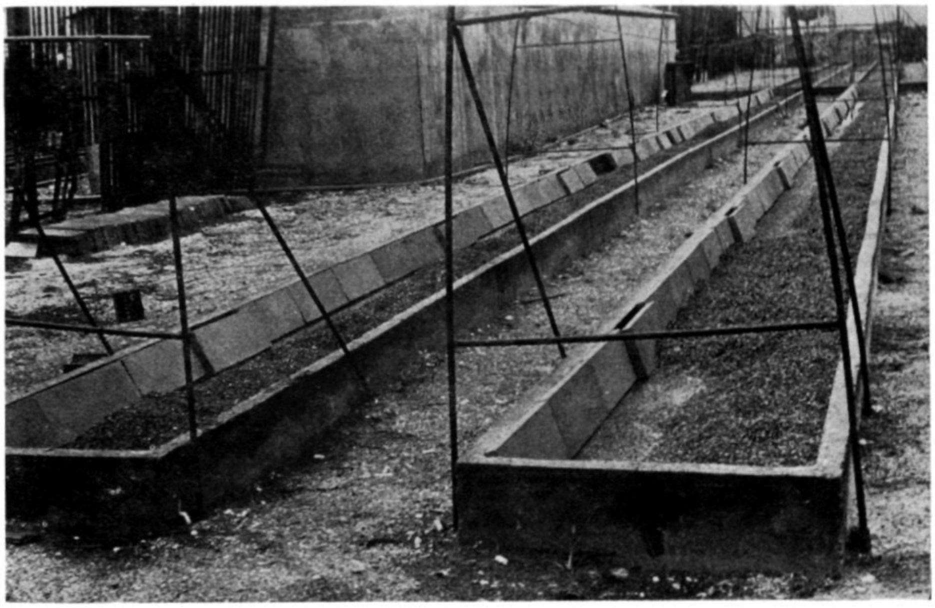

Fig. 14. Irrigation system in new unit. Compare Fig. 2.